Cryogenic Summary - Testing D2L106 in MAGCOOL (Part II)

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8/5/03

- Description
- Operating Summary
- Tests Performed
- Detail Operation
- Test Conditions
- Summary

Specific of D2L106 Test

- The joint in the LN_2 shield connection leaked during the cooldown on 6/14 and on 7/10. A brand new end plate assembly was installed on 7/14. After cold shock and leak check, the 3rd cooldown began on 7/16.

- Since tiny amount of oil was found in D2L105 after its test in May, filters are installed downstream of the cooldown and two JT supply lines for D2L106. These filters were used in preventing particulates from entering circulating compressor, ejector and turbine. In the test of D2L105, the filter is able to collect ~ 1 cc of oil in the housing with no oil found at the outlet of the filter.

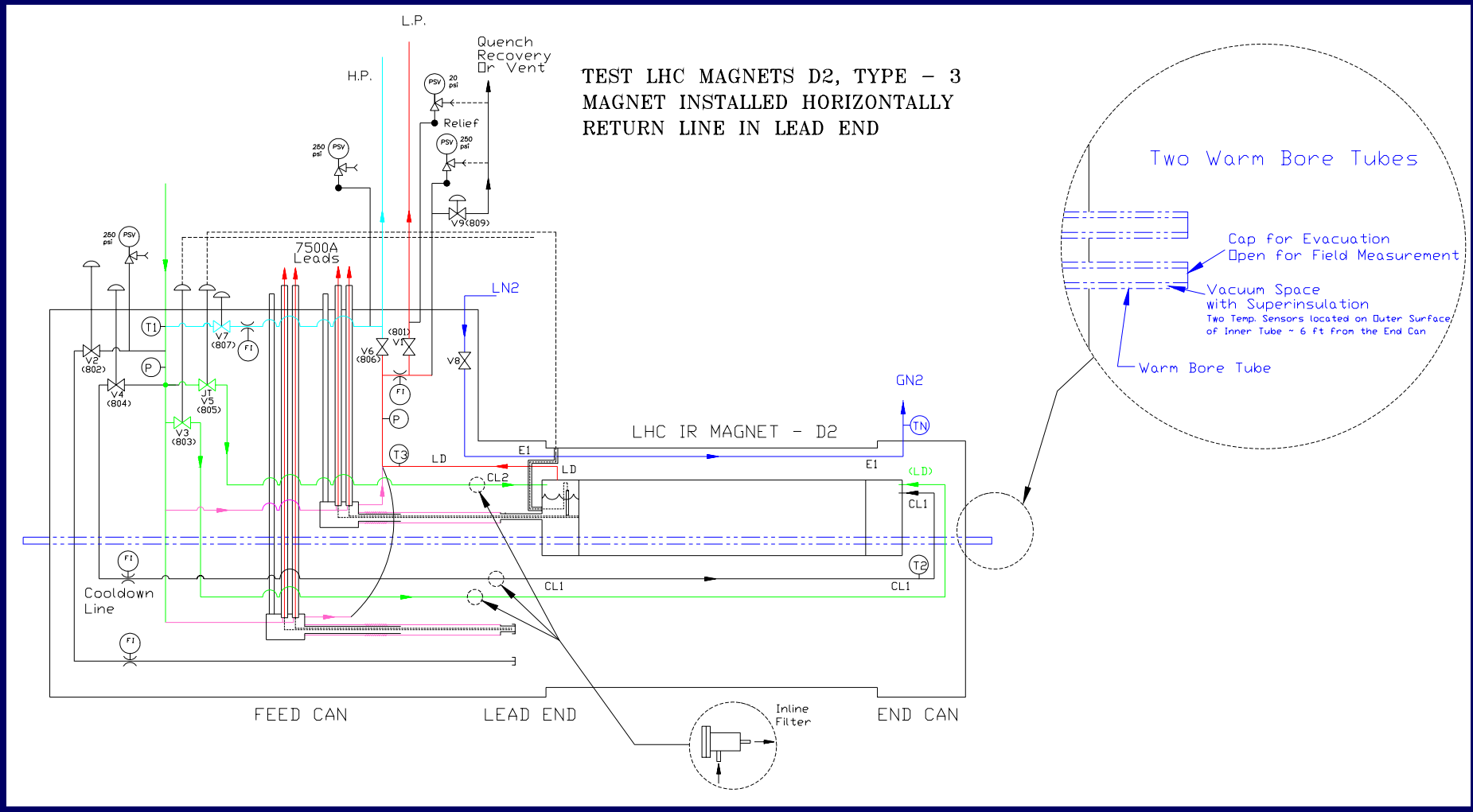
Specific of D2L106 Test

- During cooldown of D2L106, flow restriction (sign of contamination) downstream of the by-pass line in the Feed Can was experienced.
- After D2L106 was warmed up at the end of the test,
  - Very small quantity of oil, substantially less than that found in D2L105, is found at the inlet of the filter installed in the Cooldown-Warmup line.
  - Lines for the JT feed are very clean and has no sign of oil.
  - The return nozzle of D2L106 shows trace of oil film.
  - Preliminary inspection shows that there is no oil in the End Volumes of D2L106. A more detailed inspection will be performed at the time of QQS installation.

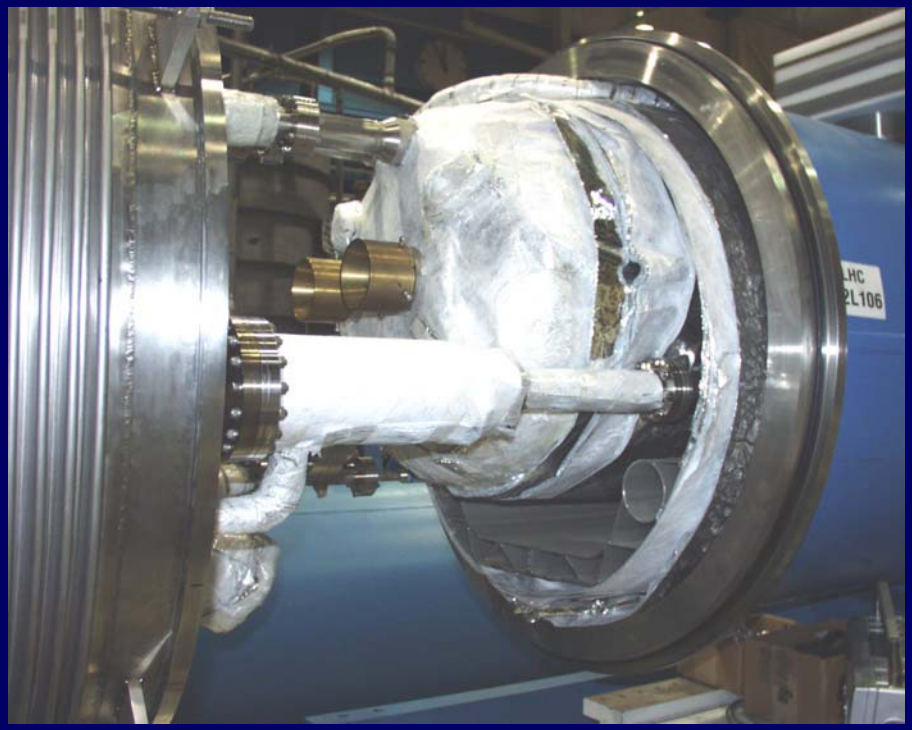
General Description - D2L106

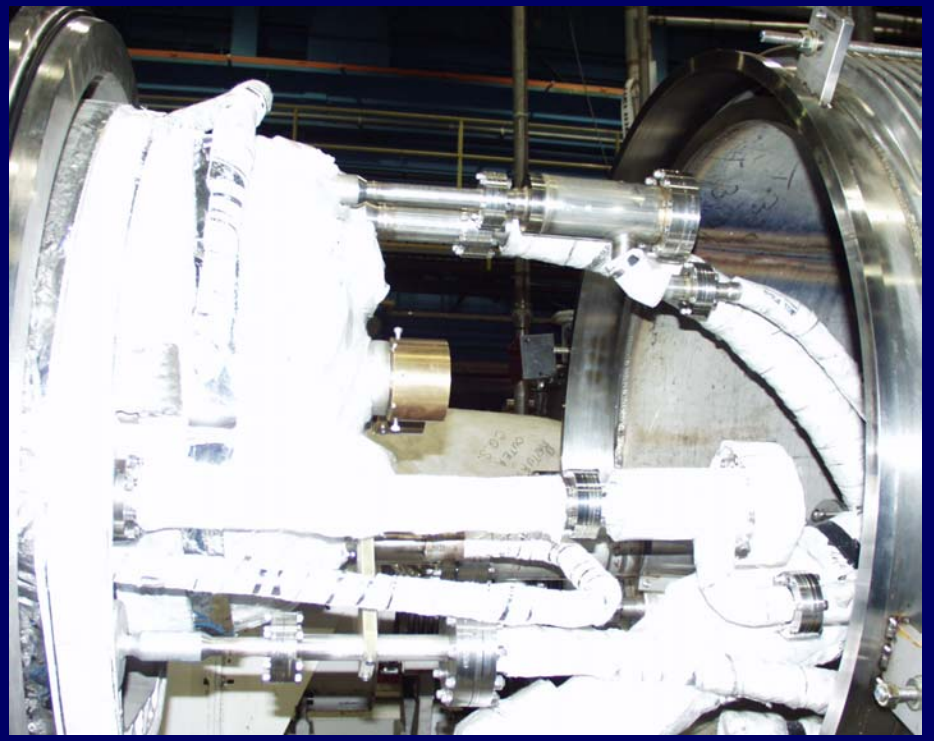
- The magnet is installed horizontally on test bay – 0% slope.
- Cooldown/warmup supply in non-lead end, helium return from lead-end.
- In liquid cool mode, JT flow are mainly fed from non-lead end similar to forced flow cooling.
- Warm bore tubes inserted. During initial quenches and field measurements, warm bore tubes were open. Some vacuum inside the bore tubes was established for ramping in liquid cool mode.
- Information on the Warm Bore Tube and measuring device can be obtained from
    - A. Marone - andym@bnl.gov
    - G. Ganetis – ganetis1@bnl.gov
    - D. Sullivan – dans@bnl.gov

Flow diagram of D2L106 with Warm Bore Tubes, Three Filters, 0% Slope and Return Line from the Lead End.

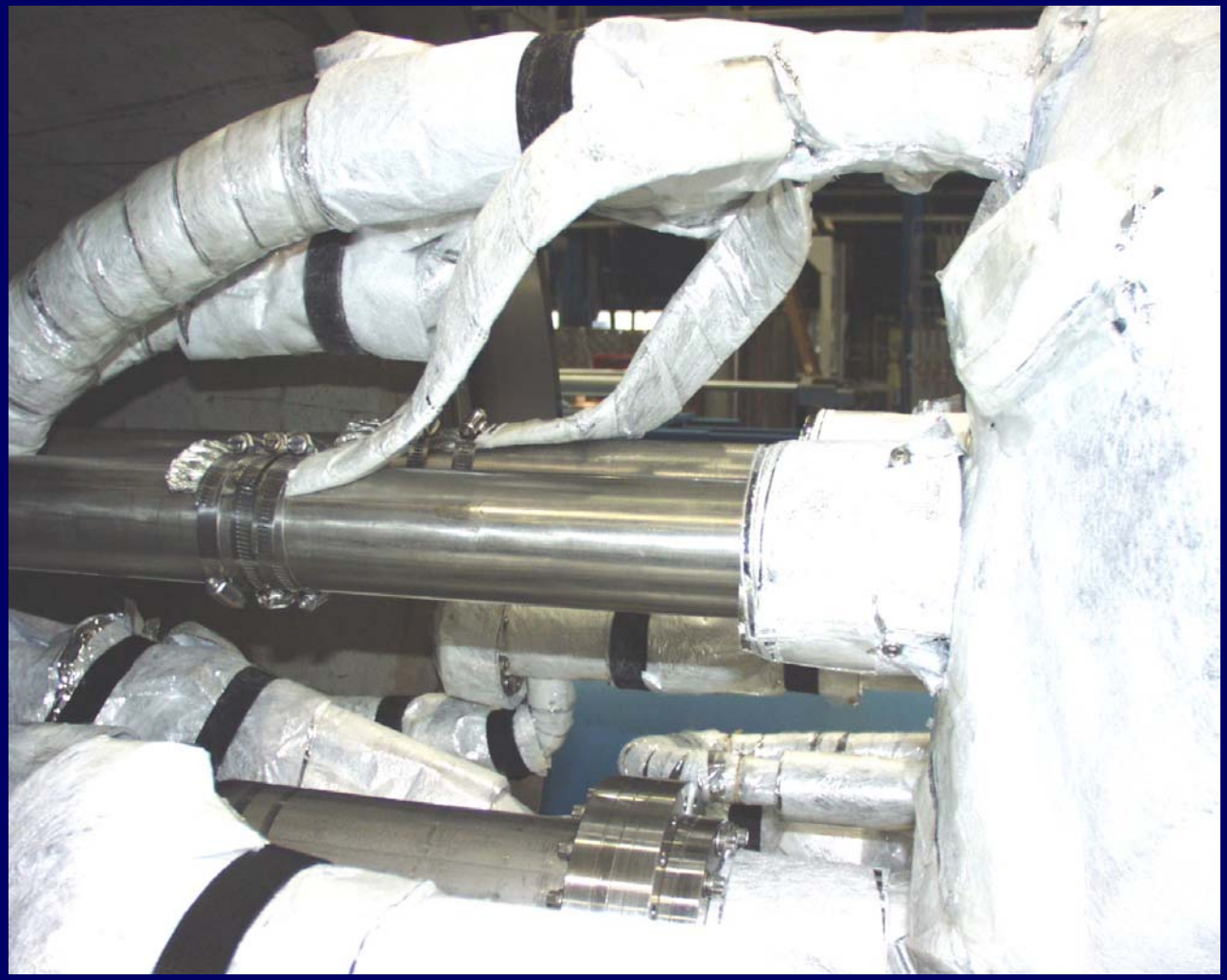


Filters in front of supply nozzles of D2L106
Left: Cooldown/warmup supply in lead end,
Right: Lower filter - non-lead end JT supply,
Upper filter - lead end JT supply.

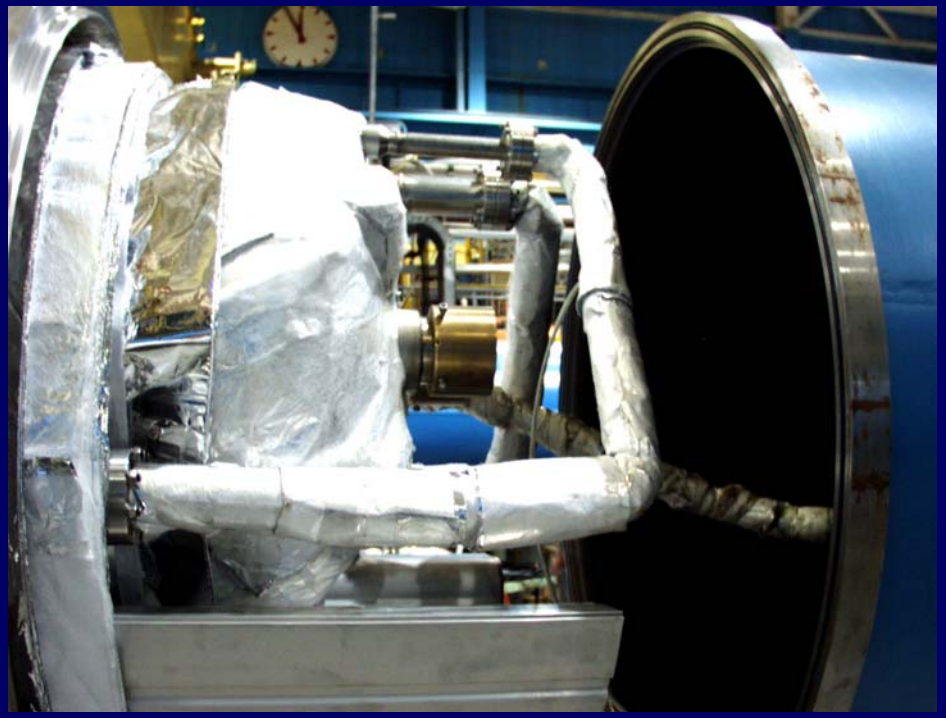


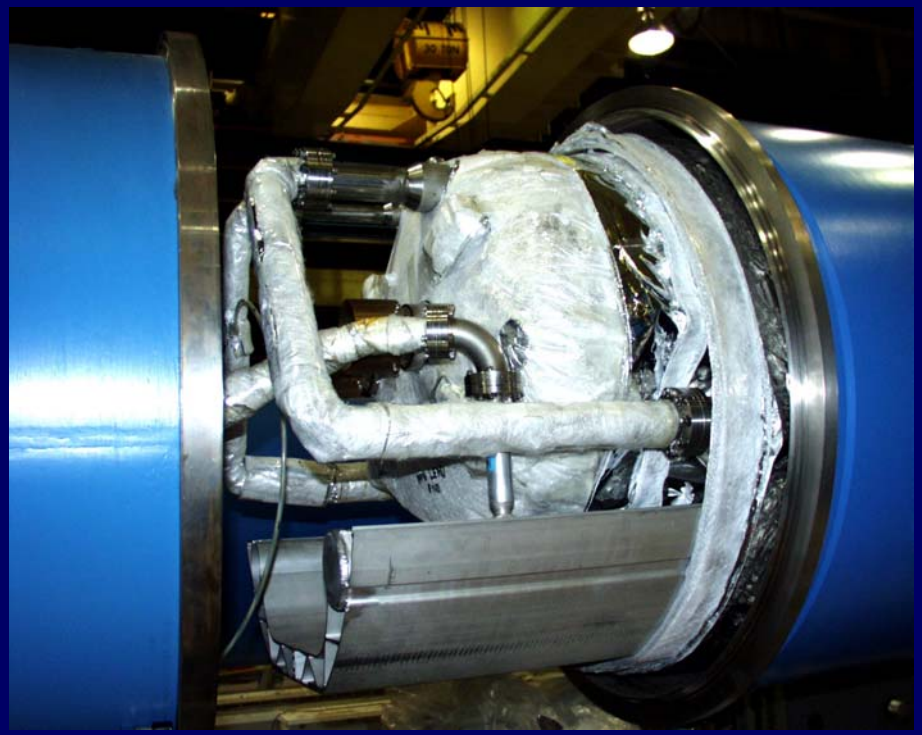


Thermal anchor of warm bore tubes, to return line, in the lead end of D2L106 (the non-lead end is anchored to Cooldown supply - not shown)



Piping Connection in the Non-Lead End of D2L106
Left: Cooldown / Warmup Supply
Right: Non-Lead End JT supply





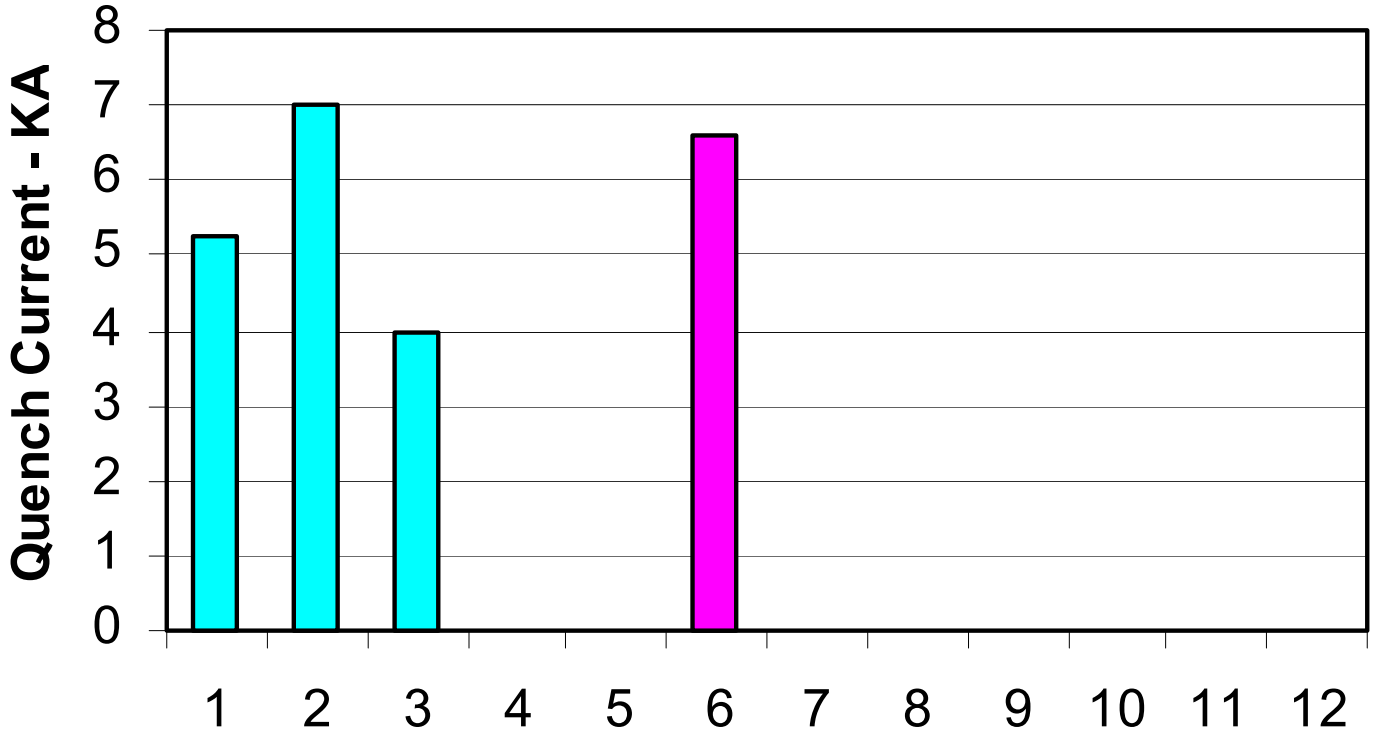
Tests Performed for D2L106

- 1st test group (forced flow cooling ~ 4.6 K),
  - Shut off - ~ 2000 A (7/21)
  - 1st quench – 5274 A (7/21)
  - 2nd quench - 7002 A (7/21)
  - Strip heater – 4000 A (7/22)

- 2nd test group (liquid cool at ~ 4.6 K)
  - Ramp to 6600 A – no quench (7/28)

Quench Performance of D2L106

(Warm Bore Tubes Open for Quench # 1 - 3, and Partially Evacuated for Test # 6)



Operation (6/19 – 7/16)

- 6/19 Repair joint on the LN2 shield line. Close vacuum enclosure and establish insulating vacuum.
- 7/7 Start 2nd Cooldown at 2 pm
- 7/8 - 9 Cooldown I
- 7/10 Leak developed, Stop Cooldown Proceed warmup
- 7/14 Replace the failed joint with new parts, cold shock and leak check
- 7/15 Close vacuum bellow, Start vacuum pump
- 7/16 Start 3rd Cooldown at 3 pm

Operation (7/17 – 18)

- 7/17 During the 1st day of cooldown, blockage in the lines occurred. The blockage cannot be cleared by pup open DOV804 as did in D2L105. Two methods have been tried:
  - » 1) Stop cooldown for half an hour and allow piping system in the Feed Can warmup above the temperature that blockage believed to have started. Blockage reoccurs ~ 1 hour after restarting cooldown.

    2) Stop cooldown and flow in reverse direction to vent helium from D2 to Purge Return Line. Appears to be successful and by increase temperature difference between supply and return, from 60 to 70 K, in Cooldown control.
- 7/18 D2 was cooled down smoothly overnight. Reach 100 K in ~ 45 hours.

Operation (7/19 – 22)

- 7/19 Start 5 K cooldown using E19 & E20 (150 rpm)
- 7/20 Reach 8 K in the morning. Continuously use E19 & E20 to cooldown.
  Liquid level in Subcooler ~ 8 PM.
  Shutdown E19 and use only E20 to avoid running out of helium in gas storage.
- 7/21 Reach test condition
  Forced flow cooling for quench test.
- 7/22 Strip heater quench
  Field measurement - 1 AC cycle, 1 DC loop.

Operation (7/23 – 28)

- 7/23 Field measurement - 1 AC cycle, 6 DC loop.
- 7/24 1 AC cycle, 4 DC loop – Finish field measurement for Left Bore,

  Move measuring coil to Right Bore – Perform 1 AC cycle and 3 DC loop.
- 7/25 1 AC cycle and 6 DC loop. Finish field measurement.
- 7/26 - 27 Stay at forced flow cooling through weekend
- 7/28 Switch to liquid mode with most flow from non-lead end to lead end. JT at non-lead end is opened ~ 59% and JT in lead end is opened 10%. Liquid level is 81% in D2.
  Ramp to 6600 A – no quench,
  Stay for 1 hour - test complete.

Operation (7/29 – 8/5)

- 7/29 Warmup.
- 7/30 Complete warmup at ~ 24:00.

- 8/1 Open vacuum bellow and disconnect lines from Feed Can.
  Inspect line and the filter in the Cooldown line.
- 8/5 No oil is found in the End Volumes using an inspection mirror.

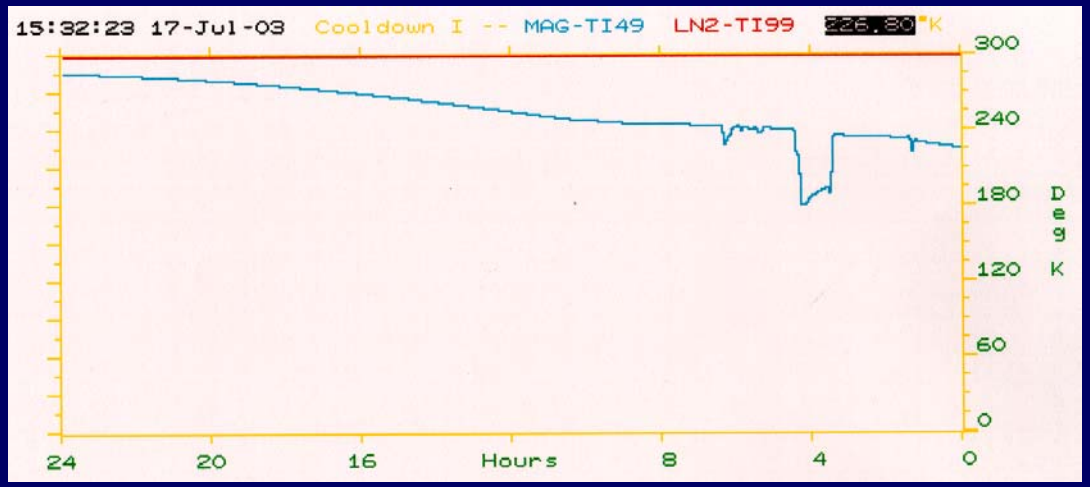
Test Conditions

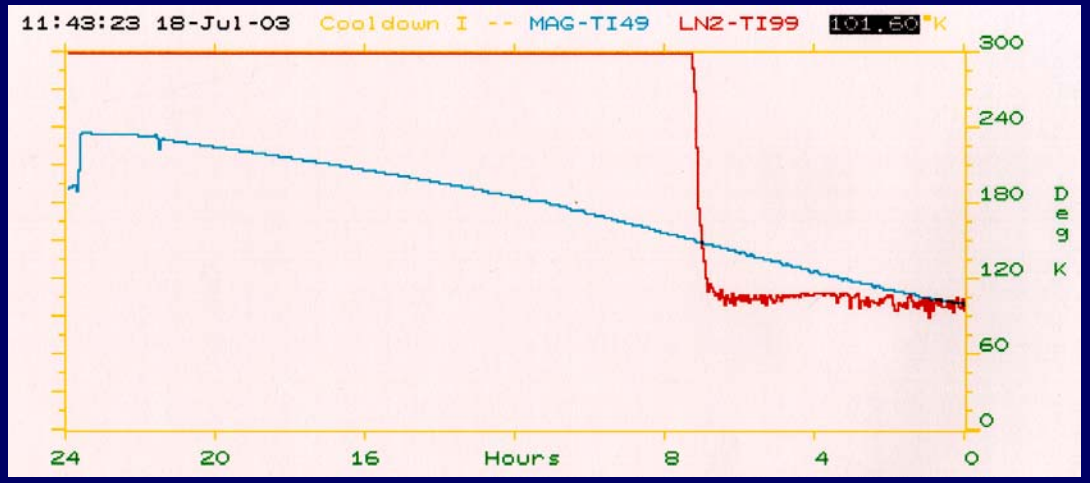
- Forced flow cooling - 12 atm, 4.52 K & ~ 60 g/s
  (Warm bore tube open)

- Liquid helium cooling – 1.43 atm, ~ 4.63 K
  Liquid level ~ 81% (~10 cm above coil,
  ~ 5 cm below vent)
  in both lead end and non-lead end
  (Warm bore tubes with some vacuum)

Cooldown from 300 – 100 K for D2L106

(7/16 – 7/18/03)

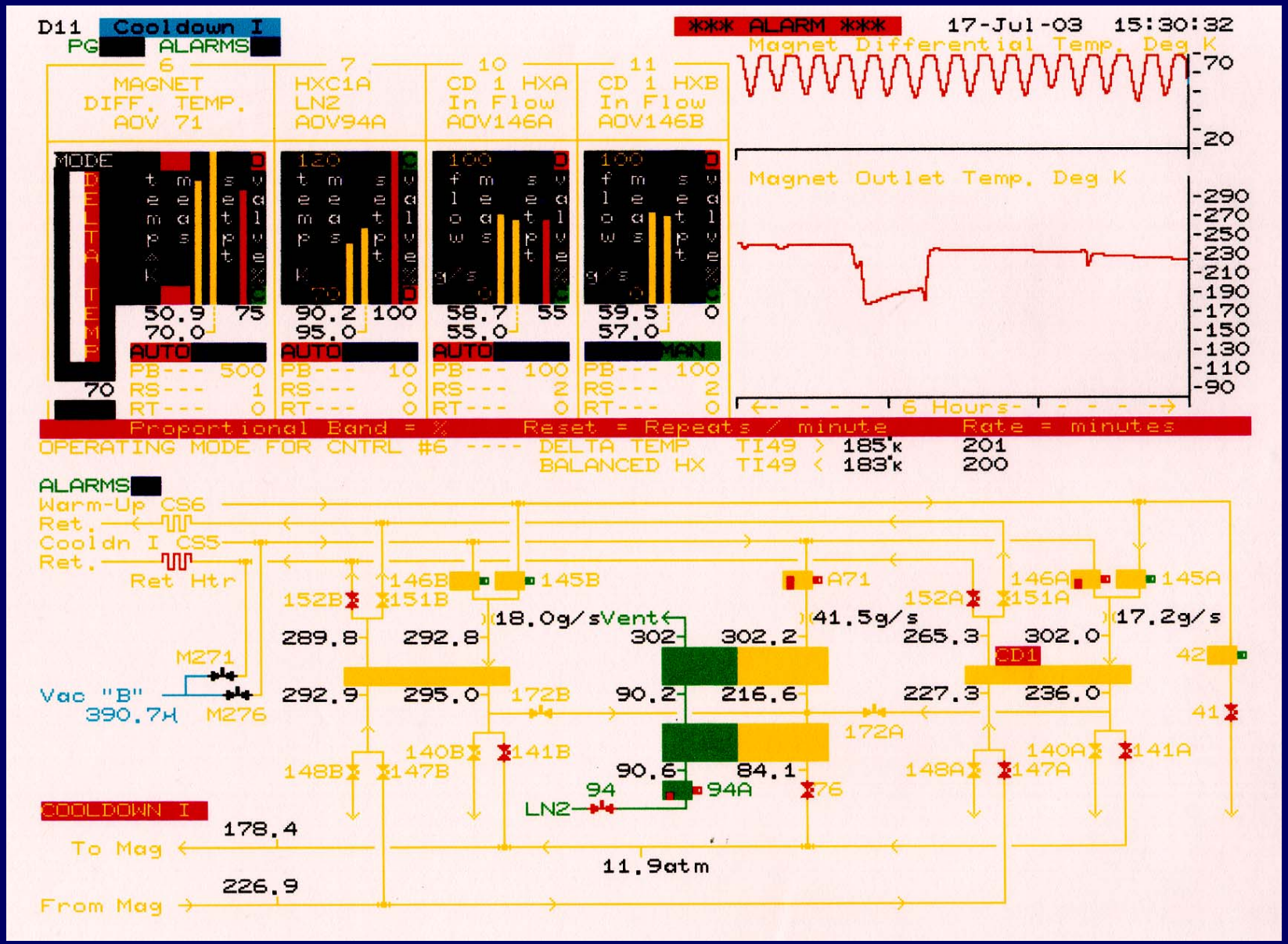




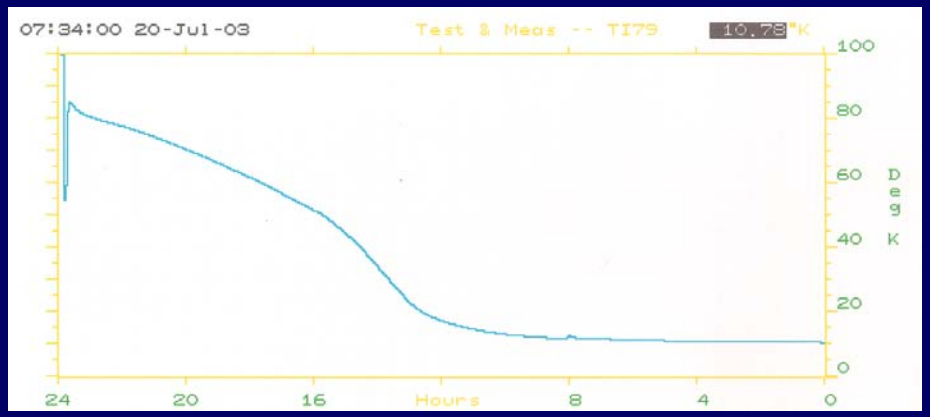
- Total cooldown time is ~ 45 hours
- Cooldown rate:

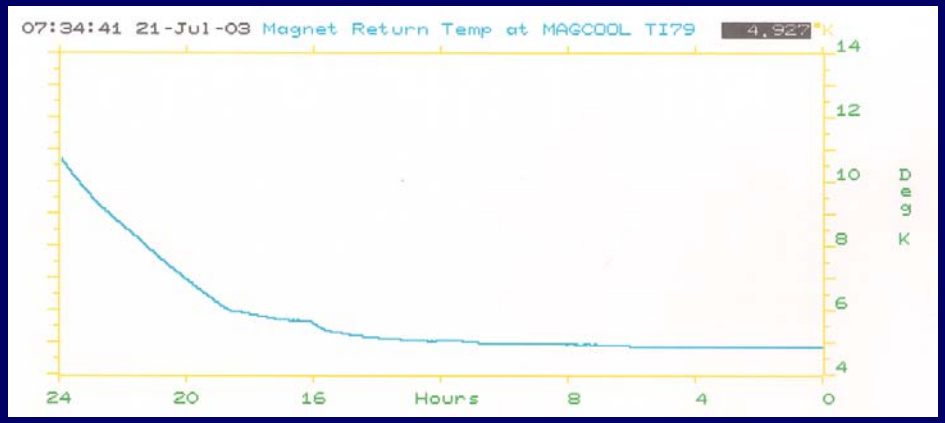
~ 3 K/hour	300 – 240 K
~ 5 K/hour	240 – 210 K
~ 6 K/hour	210 – 105 K

Operating Condition for 100 K Cooldown of D2L106



Cooldown from 100 – 5 K for D2L106 (7/19 – 7/20/03)

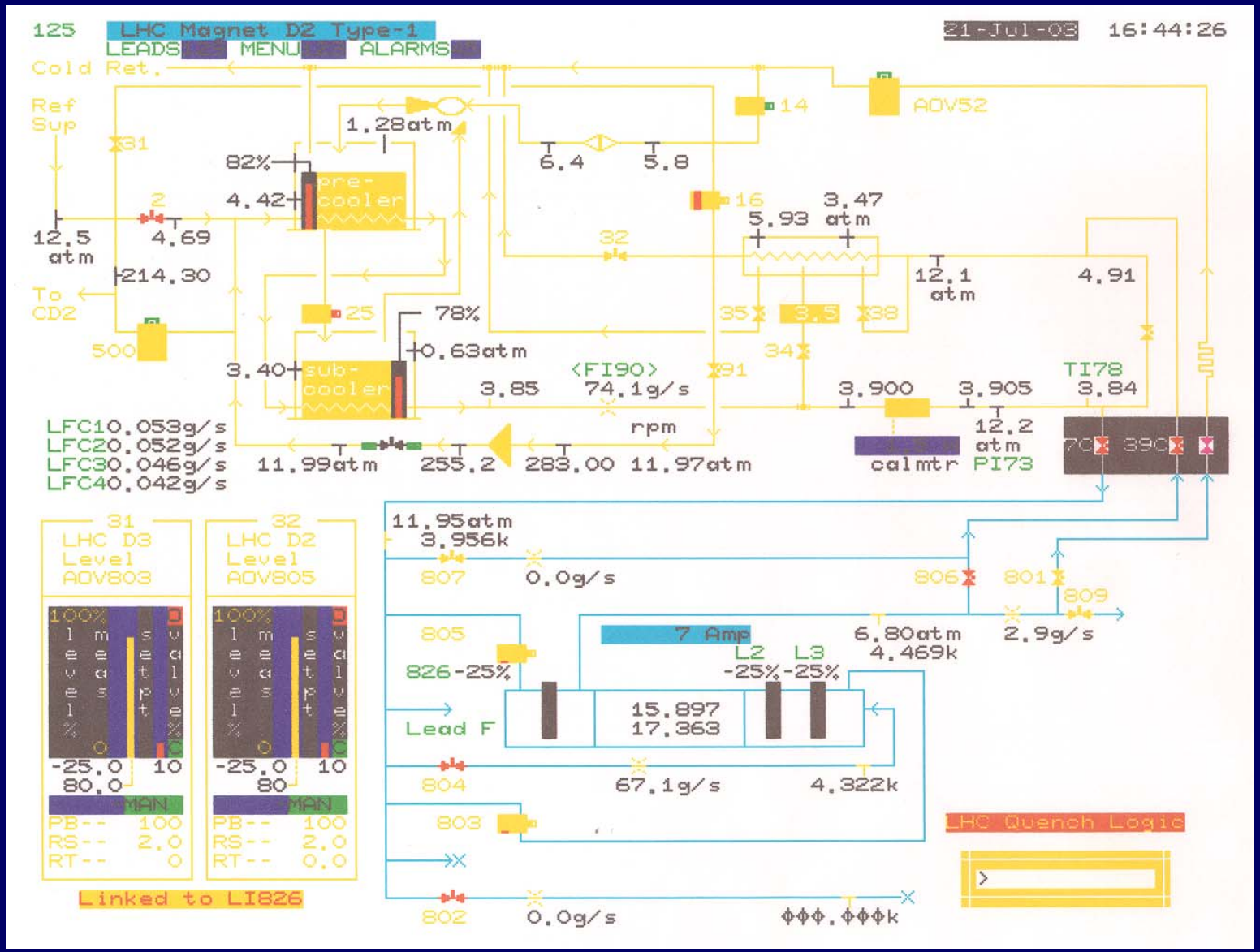




- Cooldown time (90 to 20 K) is 11 hours, ~ 6.4 K/hr using E19 & E20 (~150 rpm).
- Cooldown time (20 to 10 K) is ~ 13 hours, using E19 & E20 (at ~ 150 rpm).
- Cooldown time (10 to 5 K) is ~ 8 hours, liquid fill is ~ 6 hours
- Total cooldown time from 90 K to test condition is ~ 38 Hours

Forced Flow Cooling of D2L106 Prior to 7002 A Ramping

(Warm Bore Tube is Probably Open to Air)

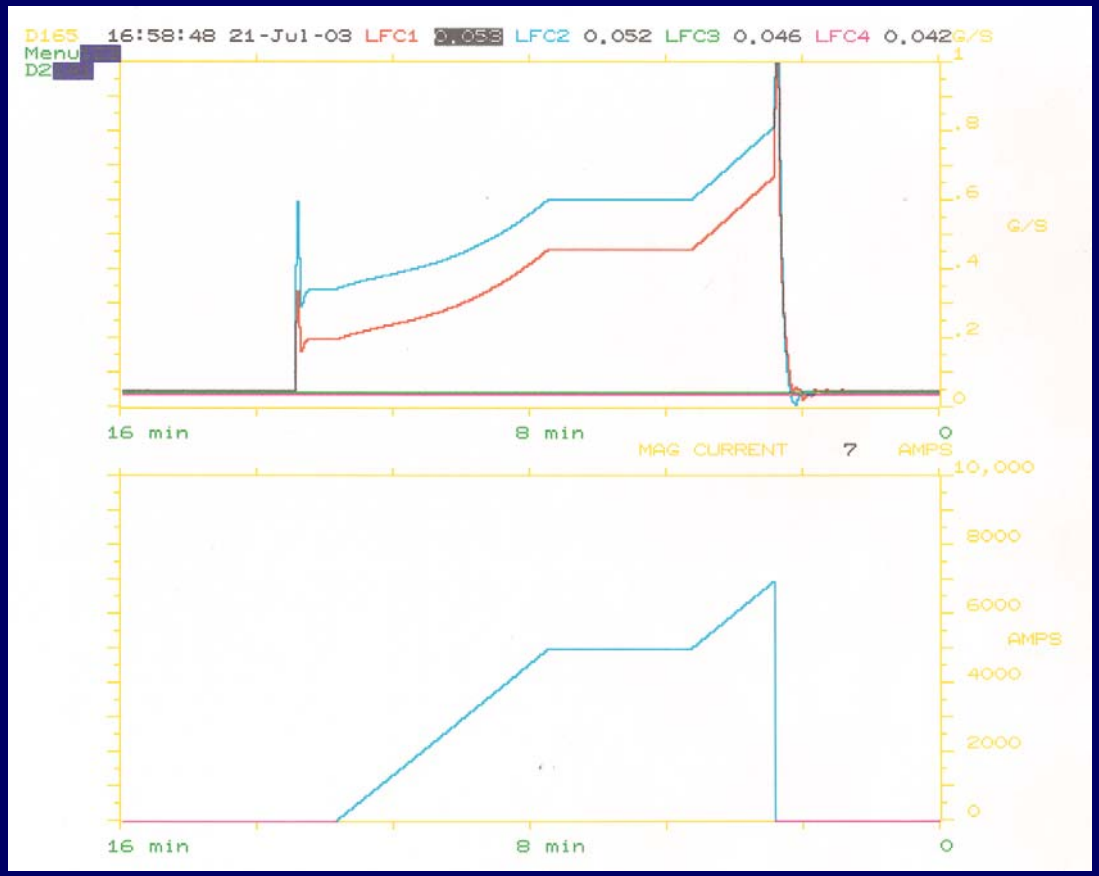


Lead Flow and Current During Ramping of D2L106

Ramp rate is 20 A/s. Below 10 A, Tare flow is 0.05 g/s. Above 10 A, Tare flow is 0.20 g/s for (+) lead & 0.35 g/s for (-) lead. Need to wait for voltage recovery of the (-) lead at 5000 A for ~ 2 min.

Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead.

Lower Figure: Current as a Function of Time



Current Leads

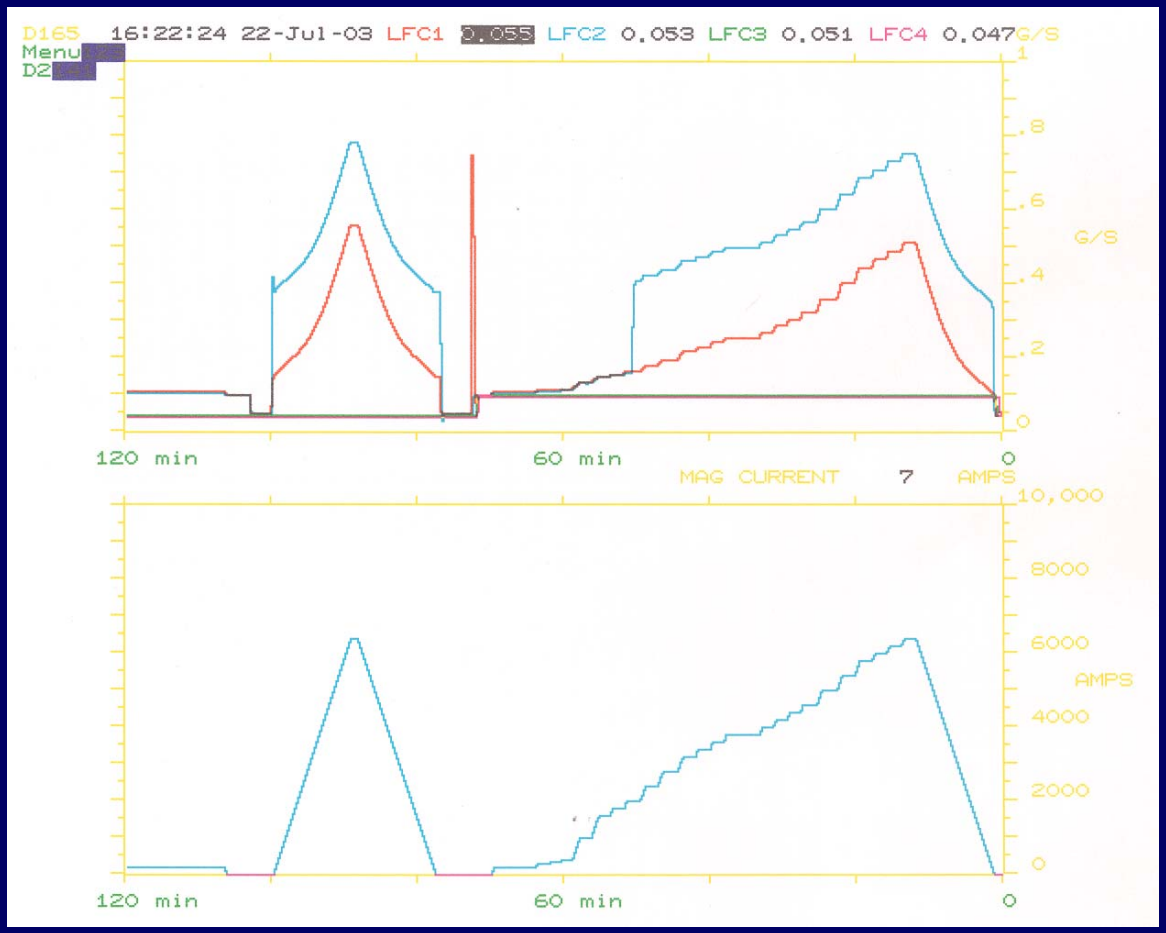
- Operate same way as previous D2 magnets.
- Separate flow controllers for the 7500 A leads. The (-) lead demands more flow than the (+) lead
  - For quench test at 20 A/s ramp rate,
    - The tare flow are 0.20 g/s for (+) lead and 0.35 g/s for (-) lead
    - Wait ~ 2 minutes at 5000 A for the (-) lead to recover the voltage developed before ramping current above 5000 A.
    - Warm end of the (+) lead becomes cold and needs to reduce Tare flow to 0.18 g/s.
    - Unused leads are set at 0.050 g/s for forced cooling and are set at 0.100 g/s for liquid cool.

Lead Flow and Current for AC Cycle (left) and DC loop (right) are the same as D2L105

Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead.

Lower Figure: Current as a Function of Time

Ramp rate is 10 A/s and is ramped to 6400 A.

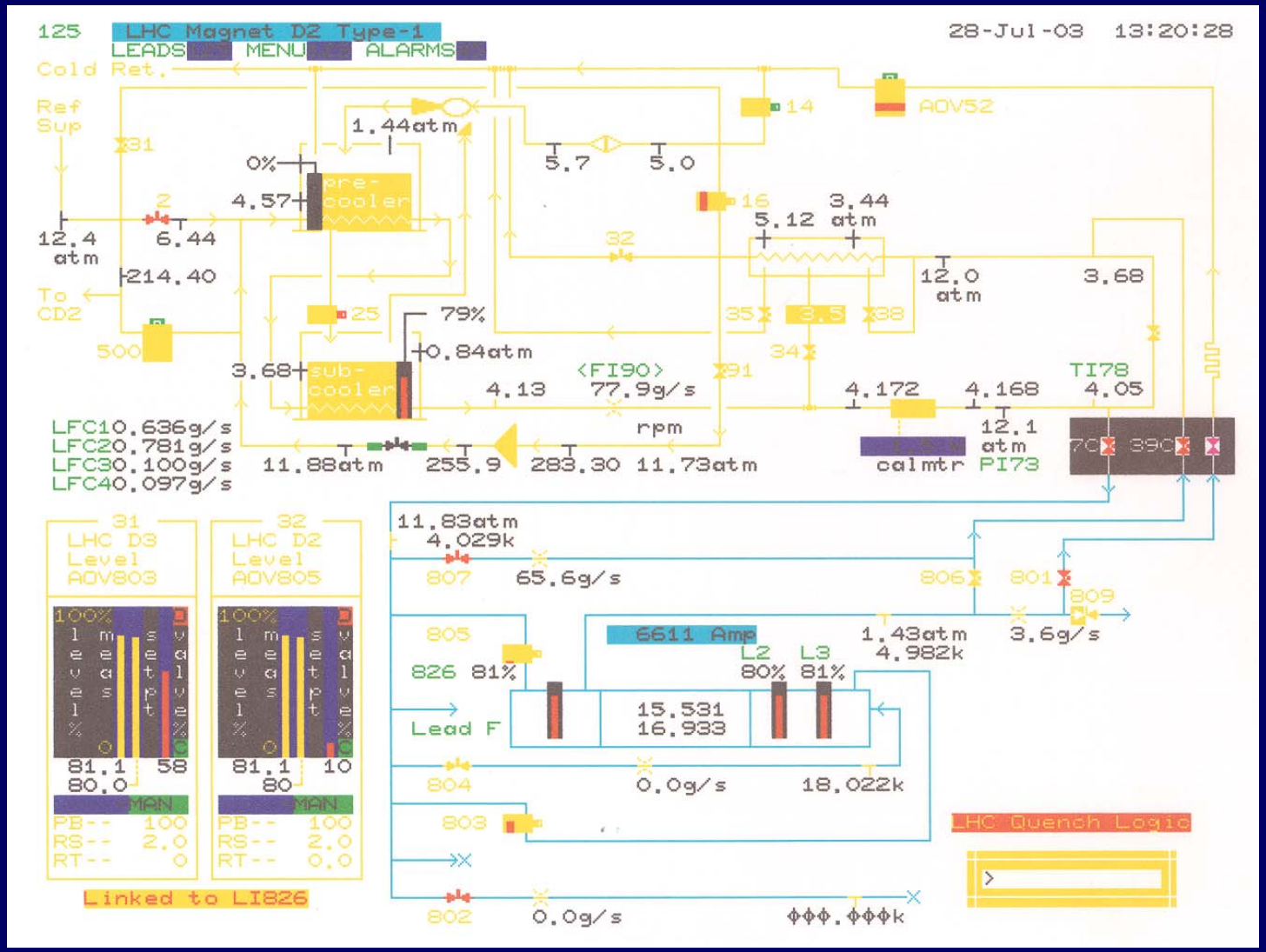


Current Leads

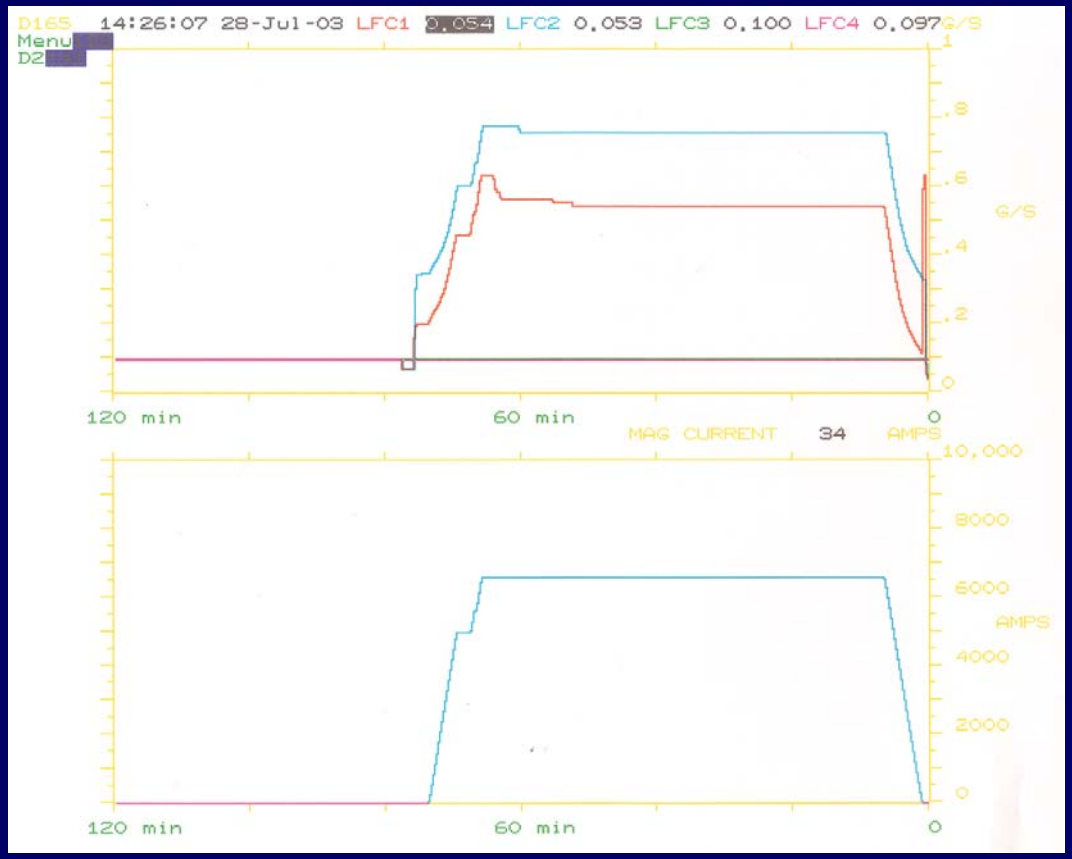
- Flow control for AC cycle and DC loop are the same as that for D2L104 & 105
  - For AC cycle at 10 A/s ramp up directly to 6400 A,
    - Tare flow is ~ 0.15 g/s for (+) lead
    - Tare flow is ~ 0.38 g/s for (-) lead
  - For DC loop at 10 A/s with 70 seconds stop at various pre-selected currents,
    - The tare flow is 0.10 g/s for (+) lead for all currents
    - The tare flow is 0.10 g/s for (-) lead below 2000 A and 0.35 g/s afterward, (or reduced back to 0.10 g/s below 2000 A with stop during ramp down)
- Unused leads are set at 0.100 g/s.

Liquid Cooling of D2L106 at 6600 A - JT Flow Mainly Fed From Non-Lead End

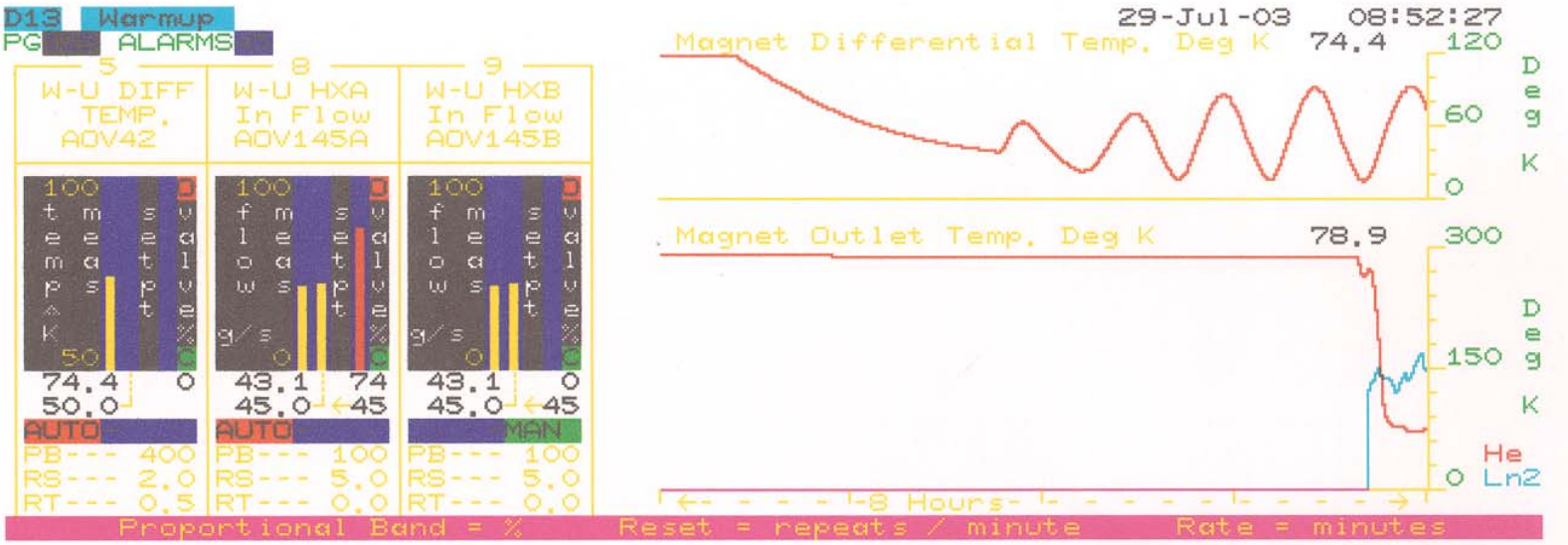
(Warm Bore Tube Evacuated with Partial Vacuum)

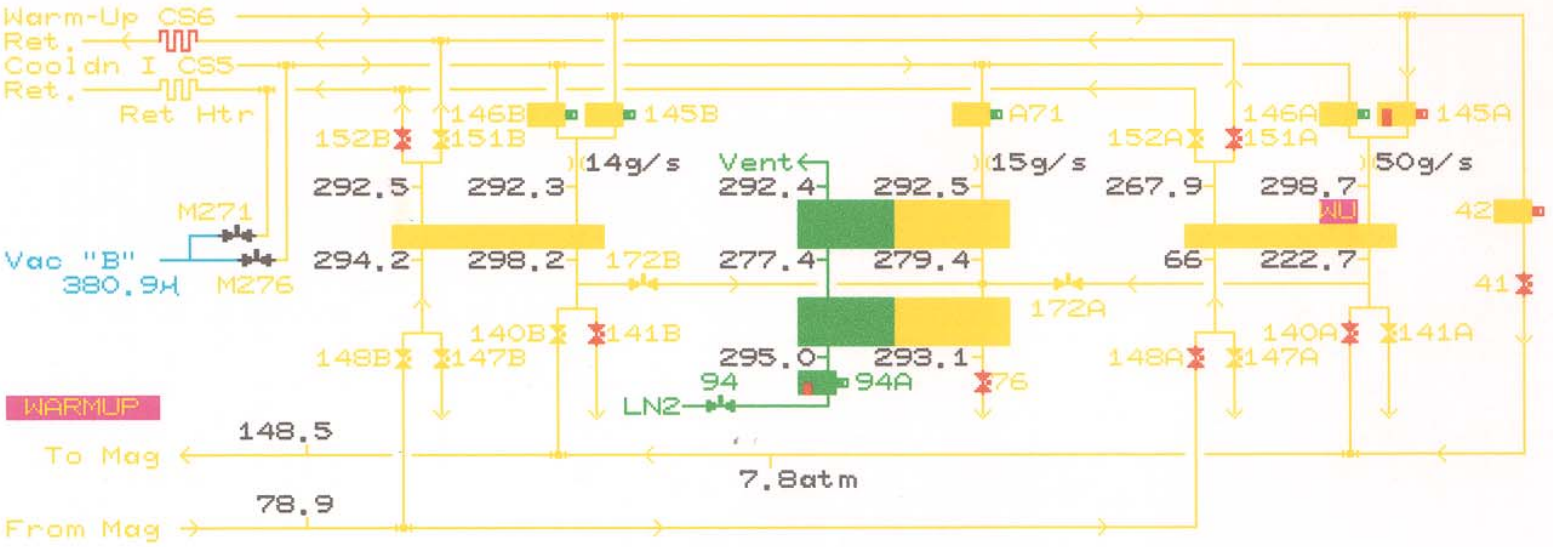


Lead Flow and Current During Ramping of D2L106 – Liquid Cool
Ramp rate is 20 A/s. Below 10 A, Tare flow is 0.10 g/s. Above 10 A, Tare flow is 0.20 g/s for (+) lead & 0.35 g/s for (-) lead. Wait for voltage recovery of the (-) lead for 2 min at 5000 A. Reduce flow slightly at 6600A. Upper Figure: Lead Flow – Blue for (-) Lead and Red for (+) Lead. Lower Figure: Current as a Function of Time



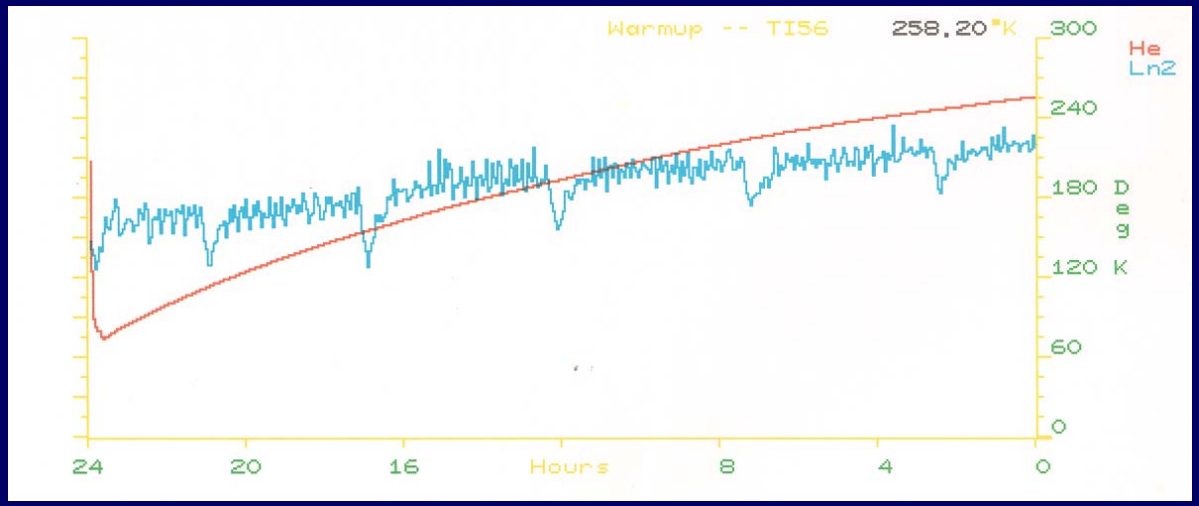
Process Control for Warmup D2L106 – 7/29/03



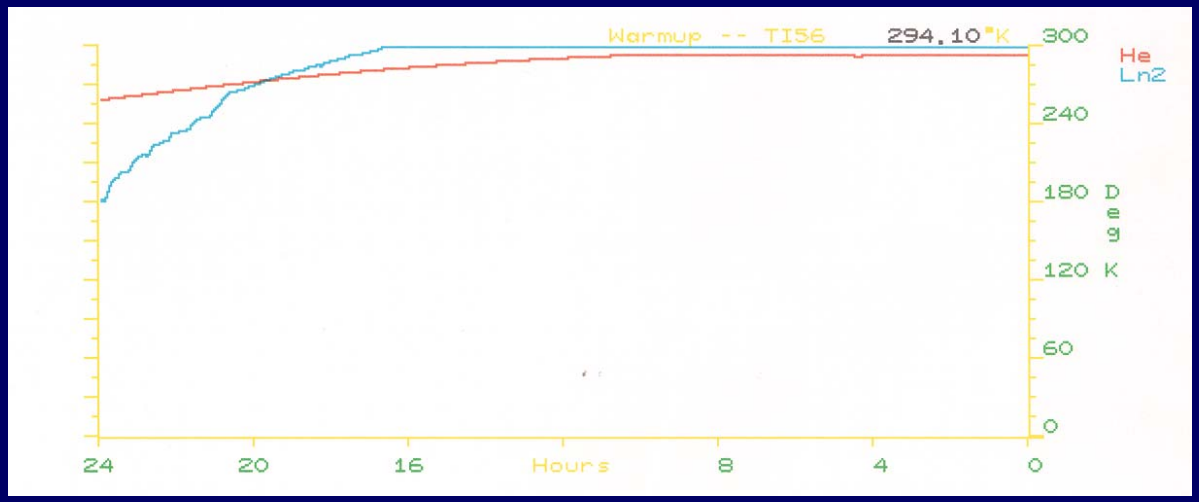


Warmup of D2L106 – from 70 to 300 K

Total time equals ~ 36 hours.

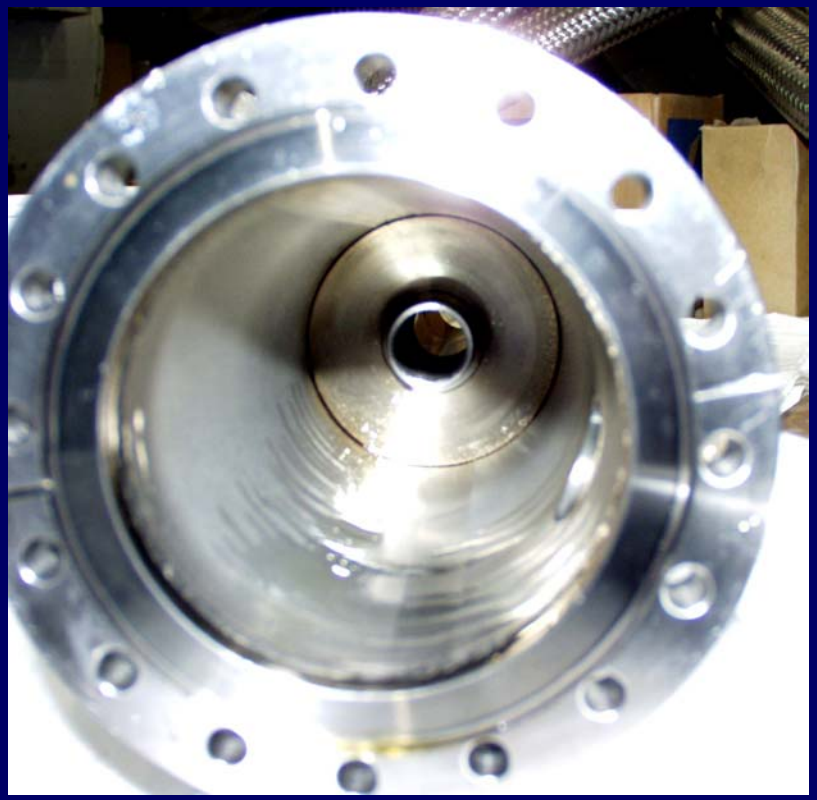


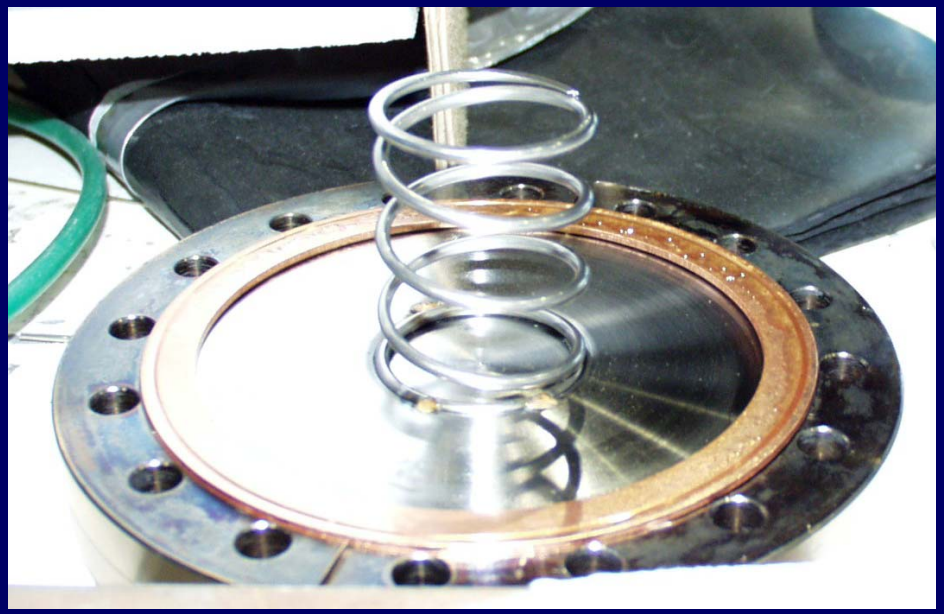
70 – 260 K
in 24 hours



260 – ~300 K
in 12 hours
Warmup
completed at
~ 12 hours on
the horizontal
axis.

Inline Filter in the Supply Line for Cooldown-Warmup





After D2L106 is warm, the filter is opened for inspection. Tiny trace of oil was found in the housing and on the copper seal of the filter in the cooldown-warmup line. The amount of oil on the filter element is minimum. Essentially no oil at the outlet of the filter. The amount of oil is substantially less than that found in D2L105.

Summary

- Complete field measurement for D2L106 with two warm bore tubes. Seal off plug for warm bore tubes are open by mistake during quench tests. In field measurement, warm bore tubes are open with 75 F nitrogen flow.

- After the magnet is warmed up at the end of the test, tiny trace oil is found in the housing of the filter installed in the cooldown-warmup supply line. Essentially no oil at the outlet of the filter. Oil film was observed in the return line. No oil is found in the JT line. No oil is found in the End Volumes of D2L106 using a mirror. A more detailed inspection will be performed at the time of QQS installation.